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APPLICATION OF LANDSAT SATELLITE IMAGERY FOR IRON ORE PROSPECTING IN THE WESTERN DESERT OF EGYPT

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SUMMARY

Prospecting for iron ore occurrences has been conducted by the Remote Sensing Center in Bahariya Oasis-El Faiyum area covering some 100,000 km^2 in the Western Desert of Egypt. Landsat-1 satellite images have been utilized as the main tool in the regional prospecting of the iron ores.

The delineation of the geological units and geological structures through the interpretation of the images corroborated by field observations and structural analysis led to the discovery of new iron ore occerrences in the area of investigation. A new locality for iron ore deposition namely that of Gebel Qalamun has been discovered accordingly, as well as new occurrences within the already known iron ore locality of Bahariya Oasis. The previously mentioned localities have been recommended for immediate detailed exploration using airborne and ground remote sensing techniques. Six other localities have been further recommended for long term exploration. The geological exploration criteria found out during the present investigation include the geological units ranging in age from Cretaceous to Eocene and the superimposed Laramide folding.

The structural features of the newly discovered Gebel Qalamun locality, as well as other new occurrences in the environs of Bahariya Oasis locality showing on Landsat satellite images are comparable to those of the already known iron ore deposits in the latter locality. The iron ore deposits of El Gedida, Gebel Ghorabi and El Harra are noted to be mostly located on crenulations representing hinge areas of meso or macro folds with axial traces attaining an approximately NE-SW direction. Moreover, the iron ore deposits at El Heiz are likewise located on crenulations representing hinge areas of meso or macro folds. However, at least two generations of folding have acted on the strata of Bahariya Oasis locality and its iron ore deposits, as the final folding traces acquire trends varying from NW-SE to NNW-SSE. The tectonic setting of the newly discovered iron ore occurrences and those of the already known iron ore deposits is controlled by the same forces which led to the deposition of iron ores in comparable localities regarding both time and space.

INTRODUCTION

A geologically favorable area for the deposition and accumulation of iron ores has been selected in the Western Desert of Egypt to conduct regional prospecting for these ores at the request of the Egyptian Iron and Steel Company. The area in question, termed Bahariya Oasis - El Faiyum area (El Shazly, Abdel Hady, El Ghawaby and Khawasik, 1976), covers 100,000 km^2 which represents 10% of the whole coverage of the Egyptian territories. Due to the great extension of the area of investigation and the limited time available to carry out the project, which is less than one year, LANDSAT-1 satellite images have been utilized as the main prospecting tool for iron ore occurrences.

As the regional prospecting for iron ores in Bahariya Oasis-El Faiyum area is essentially governed by the geological units which host the iron ores and the structures which control their deposition and accumulation, maps of geolo-

gical units, structural lineaments and drainage have been constructed for the area in question on scales of 1:500,000 to 1:250,000 based on LANDSAT imagery, intensive field measurements and structural analysis. The images used include black and white positive transparencies and prints in bands 4, 5, 6 and 7 of the multispectral scanner carried on LANDSAT-1, false color composite transparencies and prints produced from various combinations of three of the previously mentioned bands, as well as some images digitized from the computer compatible tapes.

All images have been subjected to detailed photo interpretation. It has been found out during this process and previous experience gained in the prevailing arid conditions of the Egyptian deserts that the transparencies are superior to the opaque prints and that in addition to the false color composite transparencies images of bands 5 and 7 are most helpful in delineating the geological units, structural lineaments and drainage lines.

Due to the particular importance of structural elements in the localization of iron ore occurrences the numerous field structural measurements obtained have been treated by a structural analysis technique to determine the major structures in the area of investigation which could not be fully investigated in outcrops and their geometrical elements. The technique in question is based on viewing the linear structures and the normals of the planar structures as vectors of a unit magnitude each (Ramsay, 1967; Koch and Link, 1971).

LITHOLOGIC CRITERIA FOR IRON ORE PROSPECTING

Prospecting for iron ores in Bahariya Oasis - El Faiyum area is closely connected with the identification on LANDSAT-1 imagery of the lithologic units favorable for hosting these ores, and the delineation of such units on the interpreted geological maps (Figures 2 and 3). This method is of direct nature and has been previously applied by El Shazly, Abdel Hady, El Ghawaby and El Kassas (1974) for the recognition of iron ore deposits and phosphorite beds on LANDSAT-1 images in East Aswan area, Egypt. In the latter locality the iron ores are restricted to the medium textured iron ore member which has the darkest color among the various members of the Nubian Sandstone. On the other hand, the phosphorite beds represent an integral part of the phosphate-bearing formation which is characterized by its very coarse texture and medium grey tone.

Examination of the satellite images of the investigated Bahariya Oasis-El Faiyum area reveals striking similarities between Bahariya Oasis and Gebel Qalamun environs, located in the western and eastern parts respectively of the considered area at long distances from each other (Figure 1). Iron ore deposits have been previously known at El Gedida, Ghorabi and El Harra in the environs of Bahariya Oasis where they occur essentially in Middle Eocene sedimentary rocks (Ball and Beadnell, 1903; El Shazly 1962 a and b; El Akkad and Issawi, 1963; El Bassyouni, 1972; etc.). The latter are characterized, in the appropriate LANDSAT images, by the presence of white chalky horizons intercalated by dark grey beds of limestones and clays of ferruginous nature. Sediments with comparable characteristics and age have been identified on LANDSAT images in Gebel Qalamun environs. Field investigations which followed this identification and delineation proved the presence of iron occurrences at Gebel Qalamun locality outcropping along a curve attaining some 70 kilometers in length (Figure 7). The geological unit hosting the iron deposition has been found by lithostratigraphic measurements to be correlatable to the lower formation, named Gebel Qalamun Formation, of the Middle Eocene sediments where the known iron ore deposits in the environs of Bahariya Oasis are present. In Gebel Qalamun environs the shaly horizons of the formation in question are the ones incorporating the iron minerals.

STRUCTURAL CRITERIA FOR IRON ORE PROSPECTING

The structural lineaments interpreted from LANDSAT-1 imagery are discriminated as linear elements such as fractures and faults or as curved elements representing folds. One of the great advantages of using LANDSAT imagery is the elucidation of major regional lineaments, thus enabling the detection of their interconnections and their correlation over large areas.

The structural pattern of the investigated Bahariya Oasis-El Faiyum area has been formulated in three stages starting with the delineation of the structural lineaments on the most suitable LANDSAT images, followed by checking and measuring of the structures in the field, and finally by computer programmed analyses of the structural elements.

The similarity of the structural elements, notably folds, in the environs of Bahariya Oasis (Figure 4) and Gebel Qalamun (Figure 5) has been noted at an early stage of the work as has been the case with the lithologic units. This has led to the orientation of prospecting towards the discovery of iron occurrences in the environs of Gebel Qalamun. Furthermore, the structural investigations carried out in the environs of Bahariya Oasis proved that the already known iron ore deposits are related spatially to small hinge zones of plunging synclines and anticlines imposed on the host rocks. It may be added here that Bahariya Oasis main anticlinal structure has been built up by an older folding with an axial trace striking NNE-SSW which has been modified by a younger one to acquire an axial trace striking NNW-SSE.

The same structural features noted in the already known iron ore deposits have been also encountered in other localities in the environs of Bahariya Oasis, and accordingly the latter are recommended for further detailed prospecting in three successive time periods according to their priority. In the whole area of investigation priority No.1 has been given to Northern Bahariya Oasis locality 1 (Figure 6) and Gebel Qalamun locality 2 (Figure 7). The choice of localities belonging to priority No.1 is based on favorable geological and structural conditions, the presence of iron deposition in exposures or under shallow depths, and the relative cheapness of the infrastructure required to develop such localities. Priority No.2 is assigned to Qaret Had El Bahr locality 3 and Ghard Ghorabi locality 4 in the vicinity of Bahariya Oasis, and West El Faiyum locality 5 westwards of Gebel Qalamun. Localities selected under priority No.2 possess favorable structural conditions while their infrastructure may be connected with that of localities of priority No.1. Localities belonging to priority No.3 include those of Central Bahariya Oasis locality 6, Southern Bahariya Oasis locality 7 and West Giza locality 8. The localities in question require separate infrastructure and may exist in the subsurface at considerable depths.

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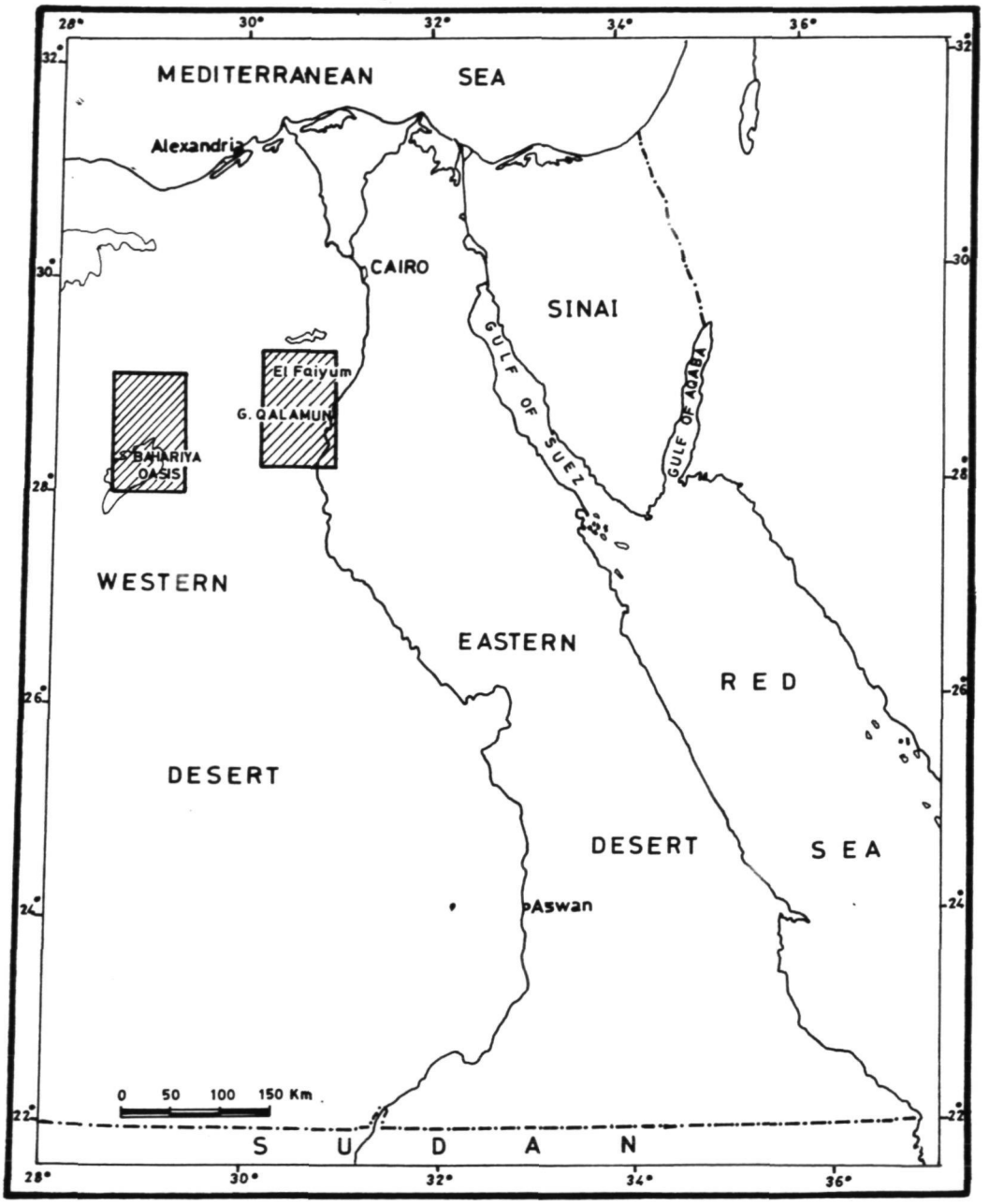

FIGURE 1. LOCATION MAP OF BAHARIYA OASIS AND GEBEL QALAMUN ENVIRONS, WESTERN DESERT, EGYPT.

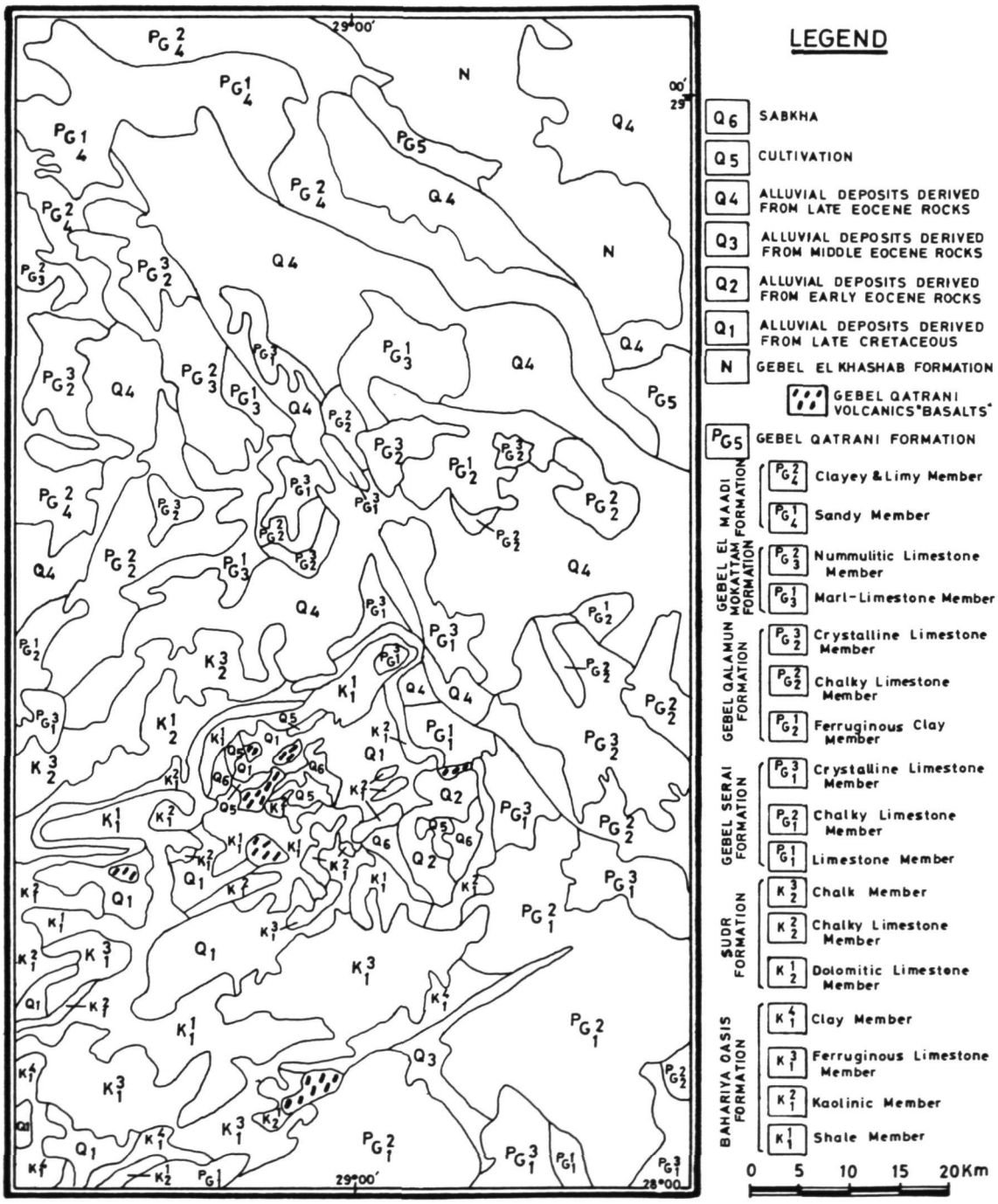

FIGURE 2. GEOLOGICAL MAP OF BAHARIYA OASIS ENVIRONS.

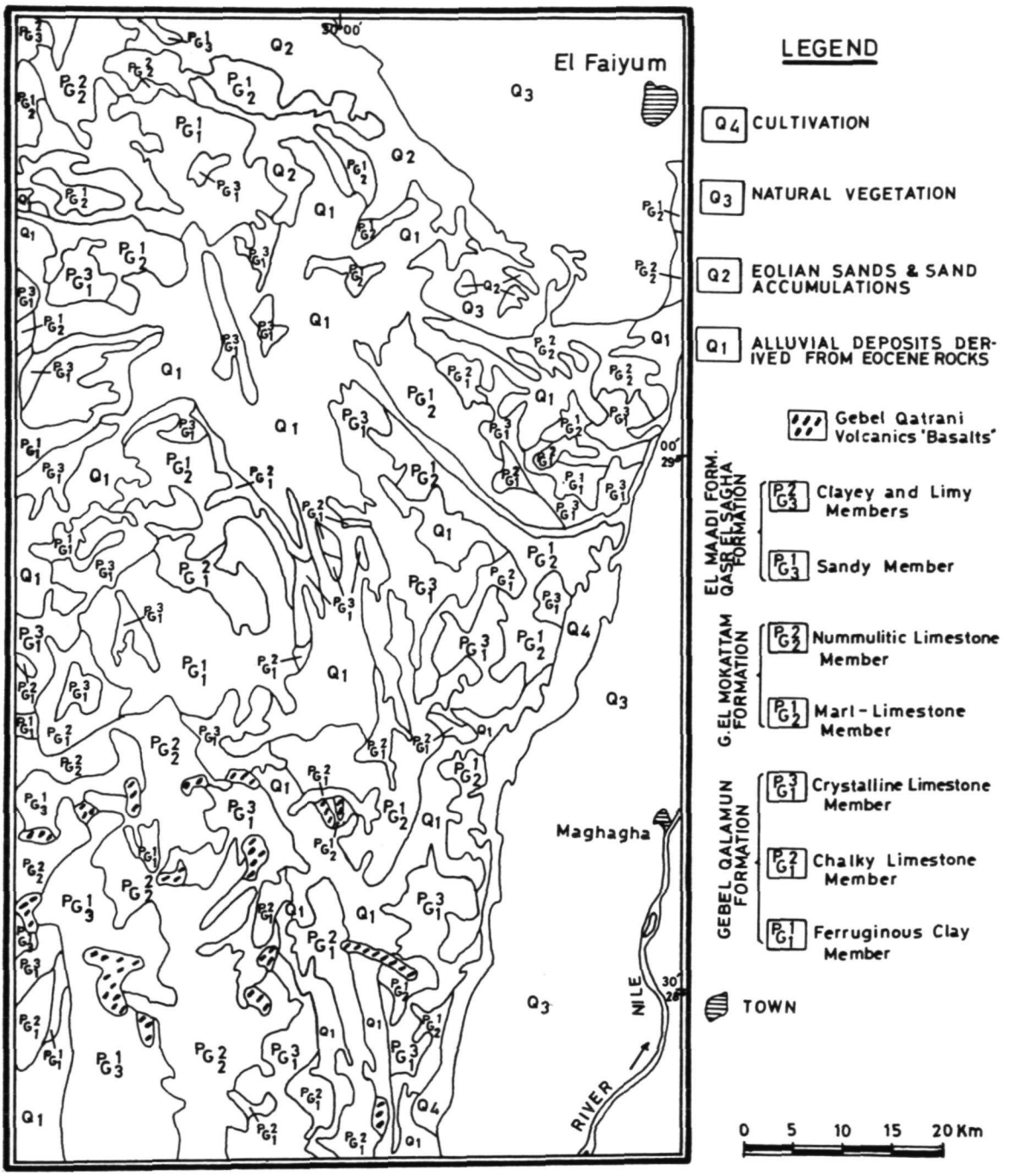

FIGURE 3. GEOLOGICAL MAP OF GEBEL QALAMUN ENVIRONS.

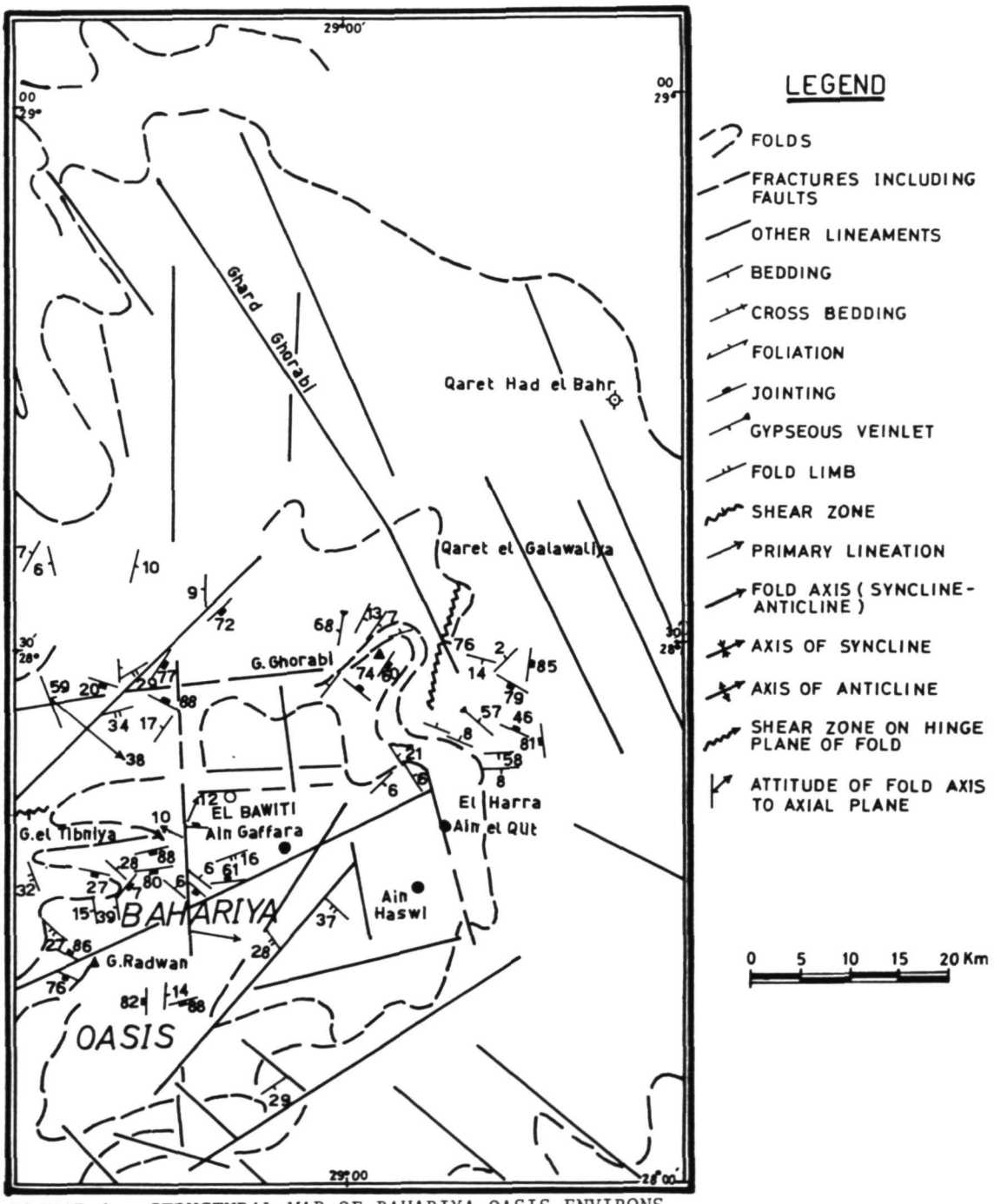

FIGURE 4. STRUCTURAL MAP OF BAHARIYA OASIS ENVIRONS.

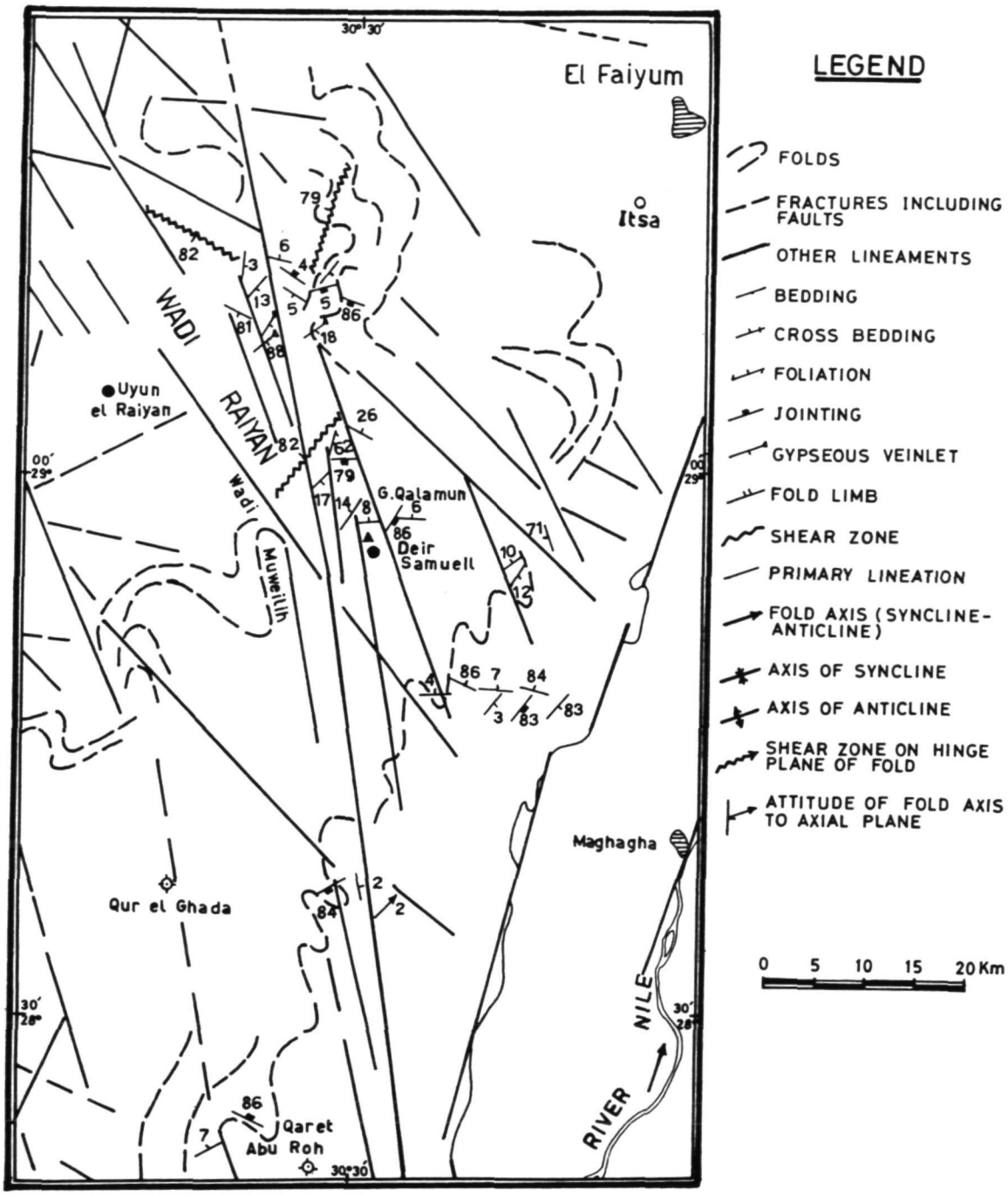

FIGURE 5. STRUCTURAL MAP OF GEBEL QALAMUN ENVIRONS.

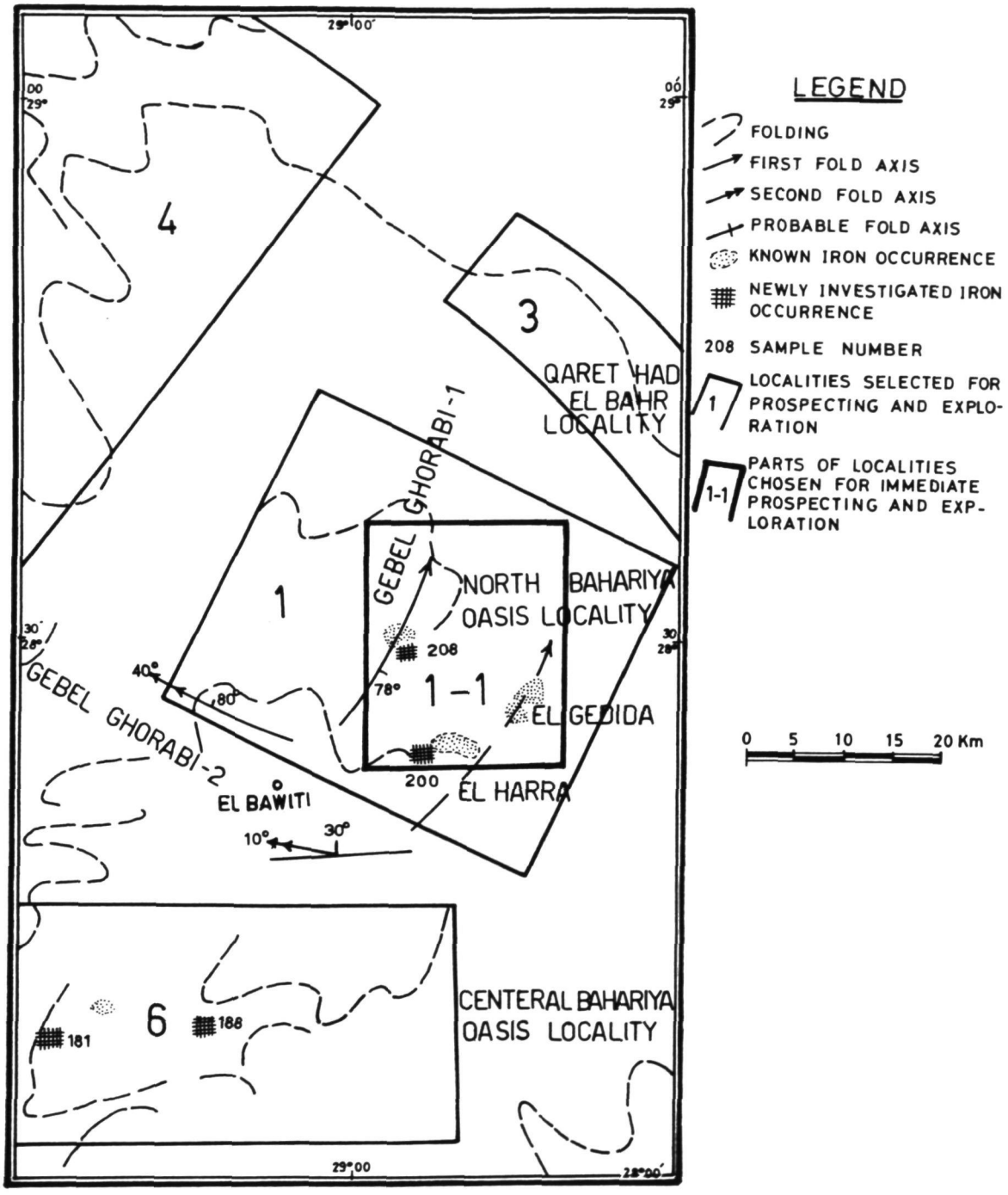

FIGURE 6. LOCALITIES SELECTED FOR IRON ORE PROPSECTING, BAHARIYA OASIS ENVIRONS.

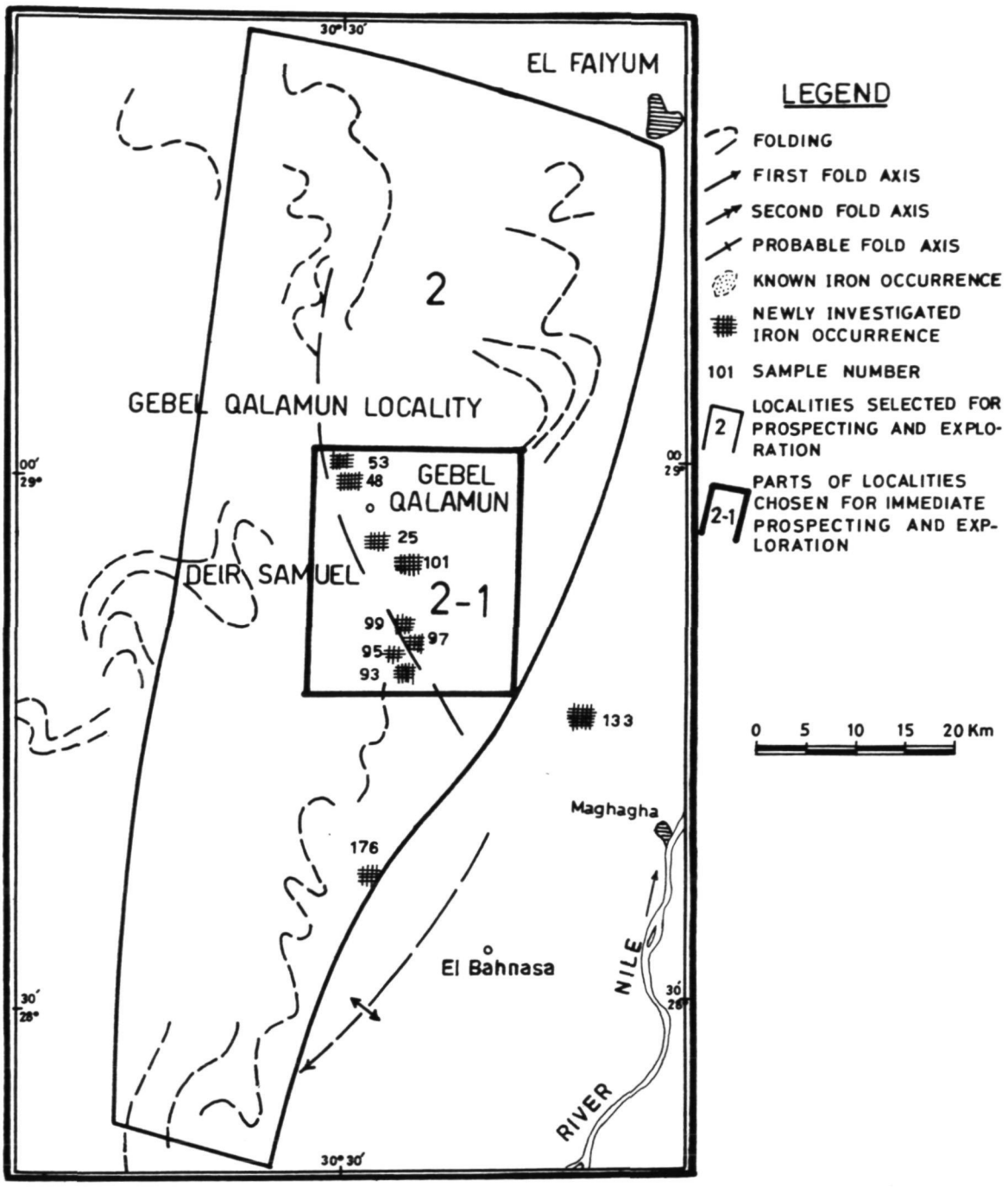

FIGURE 7. LOCALITIES SELECTED FOR IRON ORE PROSPECTING, GEBEL QALAMUN ENVIRONS.